

Aircraft noise management through controlled-area demarcation in South Africa: its application at Cape Town International airport

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Aircraft noise is a growing social, technical, economic and environmental problem, especially in developing countries like South Africa. It arises from the growth in air traffic, urbanization, uncoordinated planning around airports, and open-window living that makes physical insulation an ineffective mitigating solution. Cape Town International airport is a typical South African example of the phenomenon. Air traffic volume is steadily increasing and an additional runway has been proposed for the airport's efficient operation. The changing noise pattern requires the demarcation of a 'noise-controlled area' around the airport as the planning framework that is legally prescribed to manage this type of environmental nuisance. This paper reports the application of geographic information system (GIS) technology to define a control zone using various spatial demarcation techniques. Each alternative zone has different spatial characteristics that define and incorporate the adjacent residential communities affected as well as vulnerable land in the vicinity. An aircraft noise generation model was used to map noise intensity contours. Different spatial noise footprints for six optional demarcation criteria were used to identify affected areas around the airport. The GIS methods were then compared and evaluated to select the optimum planning approach under South African conditions.

Introduction

In this paper we demonstrate the use of various GIS-based methods to demarcate the extent of communities and land affected by noise associated with Cape Town International airport (CTIA) as a basis for noise mitigation and other alleviating strategies.

There is a growing intrusion of noise in everyday life. Anthrop¹ laments: 'The same factors that brought us air and water pollution in crisis proportions, namely increasing population, urbanization, industrialization, technological change and the relegation of environmental considerations to a position of secondary importance to economic ones, have brought us a crescendo of noise.' The advent of the internal combustion engine brought increased sources of noise on land that soon extended into the sky. Aircraft noise became a major problem with the surge in air transportation after the Second World War. The introduction and widespread use of jets by the end of the 1950s and then supersonic transport soon after created the second and third escalations in aviation noise.²

The efficiency and convenience of jet travel triggered an explosive growth in the air transportation industry and in the cities and industries it serviced. As airports grew in size and importance, the areas adversely affected by aviation noise also expanded.³ Rapid urbanization and uncoordinated planning

resulted in airport runways located too close to people's living space. Proximity to airports and aircraft noise have a detrimental affect on children's school performance,⁴ water and air pollution, road traffic congestion,^{5,6} and on housing prices and rentals, among others.^{7,8}

Aircraft noise pollution knows no political or social boundaries and affects both developed and developing countries and communities, albeit differently. According to Mato and Mufuruki,⁹ and Miedema and Oudshoorn,¹⁰ noise pollution is a steadily growing environmental problem in developing countries. There, urbanization often surges ahead of proper planning and drives the less well-off members of the population into ever closer contact with the industrial and commercial sectors where high noise nuisance levels traditionally are experienced. Moreover, developing countries, including South Africa, tend to have temperate climates and enjoy open-window living, which makes physical insulation an ineffective solution to the noise problem.¹¹

According to the Department of Transport,¹² 'there is growing concern in South Africa that the environmental impact of airports is unacceptable and inadequately controlled' and that 'many communities are displaying growing resistance to the increasing noise pollution from airports located in residential and commercial areas.' Local authorities claim that the uncontrolled increase in noise pollution from airports is 'sterilizing' major areas of developable land, to the extent that the airports are sometimes viewed as having more negative than positive effects.¹⁴ Moreover, many of the new airlines that now operate in South Africa are using old, noisy Chapter 2 aircraft that are no longer acceptable in other countries.¹⁴ Such developments fly in the face of Section 24 of the Constitution of the Republic of South Africa (Act 108 of 1996), which guarantees our people's rights to an environment not harmful to their health or well-being and one that is protected by law.

Many of the airports in South Africa are located in built-up urban areas where the adjacent development has not always taken the associated noise levels into account.¹² CTIA is a prime example of where progress in aviation was inadequately synchronized and integrated with urban planning.¹³ The airport was established in the early 1950s on the farm Belhar, then located outside the city boundary. It is now the most important airport in the Western Cape province and the second busiest in South Africa, handling 17% of the international and 30% of all domestic passengers.¹⁵ Passenger traffic is expected to grow strongly from 6.5 million in 2004 to 14 million by 2015¹⁶ — a higher rate of growth than the expected world average in the medium term.¹⁵

The airport is located approximately 20 km east of the city centre (see Fig. 3) and is connected to the city by the N2 highway. The airport is approximately 900 ha in area and is surrounded by mostly low-status residential and some light industrial development in its immediate vicinity. Despite speculation to the

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contrary, for cost reasons CTIA will not be relocated.¹⁷ Rather, to cope with the projected increase in air traffic, an additional runway has been proposed that will initially reduce site impact due to traffic redistribution, but will affect a larger area. It is, therefore, necessary to improve noise management by planning correctly for potentially affected areas. One way this can be achieved is by designating a 'controlled area' in terms of provincial noise regulations¹² as part of the legal requirements for an environmental impact assessment for the second runway.

This paper explains the method involved in the calculation and mapping of aircraft and noise intensity paths in GIS. More specifically, we demonstrate the various demarcation methods available and evaluate the results empirically to decide on an optimal demarcation strategy that is suitable for all major airports in South Africa.

Aircraft noise modelling

Many airports compute noise exposure directly using noise monitoring instruments at sites at and around the airport. This method is expensive and time-consuming, however, and quantifies only the current level of noise exposure. To calculate the impact noise generated by air traffic in the future and to perform scenario studies, noise patterns can be computed through simulation models. These predictive and descriptive tools are capable of depicting noise propagation and quantifying its influence on surrounding communities. They are capable of integrating airport geometry, noise levels, atmospheric conditions, and the behaviour of specific aircraft into a single, unified picture of noise exposure patterns in and around airports. Aircraft noise models can also compare predicted and actual sound levels through a process of model validation.¹⁸

The noise model

An aircraft noise model consists of a suite of equations that describe the relationships among various factors contributing to the intensity and distribution of the noise. Typically, a model has three main components:

- the core equations — computational algorithms for calculating the sound level produced, on average, by a specific type of aircraft performing a specific operation and for calculating cumulative noise levels by all aircraft using the airport of interest;
- an aircraft data base containing the noise and performance characteristics of each type of aircraft operating at an airport;
- additional inputs for environmental factors affecting sound levels (typically airport elevation, temperature, atmospheric pressure, wind direction and speed, and runway gradient) as well as operational information such as traffic mix, runway usage, and flight tracks.¹⁸

Variants of the models in practice

Various models are used for noise management at airports around the world, depending on such considerations as ease of calculation, sensitivity to affected communities and willingness to address environmental nuisance to benefit the quality of life in adjacent suburbs or legal requirements enacted to manage and guarantee acceptable quality of life of citizens. We discuss two models and compared them with the best noise descriptor or metric generated in these models.

The Integrated Noise Model and the Aircraft Community Noise Impact Model

The Federal Aviation Authority (FAA) in the United States has developed the Integrated Noise Model (INM) to evaluate the

effect of aircraft noise in the vicinity of airports. The INM has been the FAA's standard tool for this purpose since 1978. The model uses flight track information, aircraft fleet mix, standard and user-defined aircraft profiles and terrain as inputs and produces noise exposure contours. It includes built-in tools for comparing contours and utilities that facilitate easy export to commercial GIS. The model also predicts noise at specific sites such as hospitals, schools and other sensitive locations in the vicinity of the airport.

The Aircraft Community Noise Impact Model (ACNIM), which combines several existing aircraft noise models with a full-featured geographic information system and with flight trajectory optimization software, was developed by Wyle Laboratories for the National Aeronautics and Space Administration (NASA). The ACNIM enhances the INM by providing a more detailed population and land-use analysis of noise-affected communities surrounding airports. It produces optimized flight trajectories that serve the purpose of minimizing community noise impacts. The model helps the user visualize how alternative scenarios would increase or decrease the number of people affected within each noise contour level by distinguishing between populated and unpopulated areas when performing population and housing counts. The result is a 'smarter' population impact analysis.¹⁹ Figure 1 shows how GIS integrates into the two models.

Whereas flight track information, aircraft and locational information feed into the INM to produce noise contours, GIS and the addition of optimized flight trajectory software to generate community impact scenarios with planning implications can enhance this output in ACNIM.

The DNL airport noise metric

Many noise metrics exist and the INM can produce contours in many different measures. However, the noise descriptor used in our research is the Day-Night Average Sound Level (DNL). The DNL is the 24-hour average sound level, in decibels, obtained from the accumulation of all events, with the addition of a 10-decibel penalty to sound levels during the night from 22:00 to 06:00 or 07:00. The weighting of night-time events accounts for the increased interfering effects of noise during the night, when ambient levels are lower than by day and people are trying to sleep.³

The meaning of various noise metrics requires further explanation. One decibel is the smallest difference between sounds detectable by the human ear and is measured in units of decibel

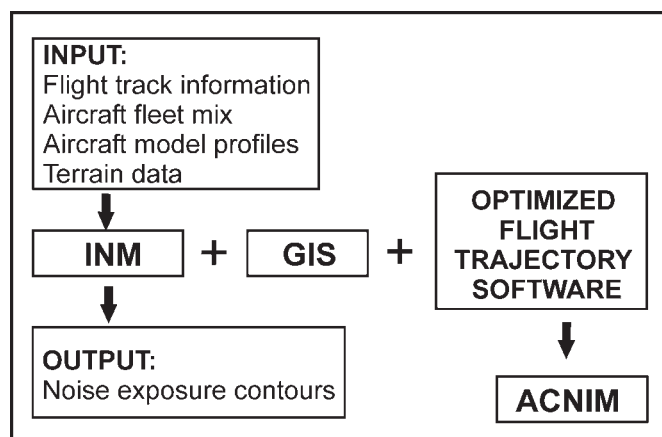


Fig. 1. The relationship between the Integrated Noise Model (INM), the Aircraft Community Noise Impact Model (ACNIM) and geographical information systems (GIS).

(dB). Measured along a logarithmic scale, it means that a 5 dB noise difference amounts to about a 30% change in detectable intensity.²⁰ The factor of 10 multiplying the logarithm makes it decibels instead of bels.²¹ The dBA metric (the unit used to express sound level measured through the A-weighting network of a sound-level meter) can be defined as a single-event sound-level measure used to describe average peak noise levels of aircraft flyovers²² measured in decibels. The DNL metric is a cumulative average value derived from measurements made in dBA.¹⁵ It is important to keep the logarithmic nature of dBA in mind. It means that for management a wide range of sound intensities can be compressed into a comprehensible scale that ranges between 0 dBA, at which sound can barely be heard, to about 120 dBA, at which sound can cause physical pain from excessive exposure. A large commercial jet aircraft, when 150 m overhead, can generate more than 115 dBA.¹⁵

The INM output: noise contours

The output of the INM is a set of spatial noise contours of equal sound exposure level. The spatial noise impact of a single aircraft is often referred to as a 'noise footprint'. The cumulative spatial effects of a series of individual aircraft operations over a specified time are generally referred to as 'noise contours'.¹⁸ The INM computes spatial noise levels at finite points on a grid, which are then plotted and interpolated to create noise contours. Figure 2 indicates the average annual aircraft flight path noise intensity contours constructed from a variety of sources.

Noise contours provide the guidance necessary to make sensible land zoning and planning decisions, but there are several factors to be taken into consideration when they are used in decision-making. First, noise contours are fuzzy boundaries, which means they tend to be uncertain and often shift with time.²³ Consequently, it is important not to see noise contours as rigid boundaries when decisions are made. Second, noise contours become fuzzier as the exposure level decreases and more discrete and sharper as the exposure level increases. This is because the INM's ability to compute noise exposure accurately degrades rapidly beyond and, thus, below the 60-DNL contour line, due to complex aircraft interactions and routings that occur at this distance from the airport. For example, a 55-DNL contour would be rather fuzzy, whereas a 75-DNL line would be sharply in focus.²⁴ Third, the accuracy of noise contours can be challenged when local conditions are not similar to the standard field conditions adopted in the DNL method, and the area exhibits atypical geographical characteristics. Pereira-Filho *et al.*²⁵ found that many complaints arose when noise contours were implemented as rigid guidelines regardless of local conditions.

Airport noise control and modelling in South Africa

During the 1960s, the government realized the need to predict noise caused by aircraft operations around all major airports in South Africa.¹⁷ In 1966, an interdepartmental committee was established and entrusted with the task of investigating the problem of noise around airports.²⁶ This committee sponsored an investigation by the Council for Scientific and Industrial Research working in collaboration with the South African Bureau of Standards (SABS), and assisted by several government departments, local authorities and South African Airways. The

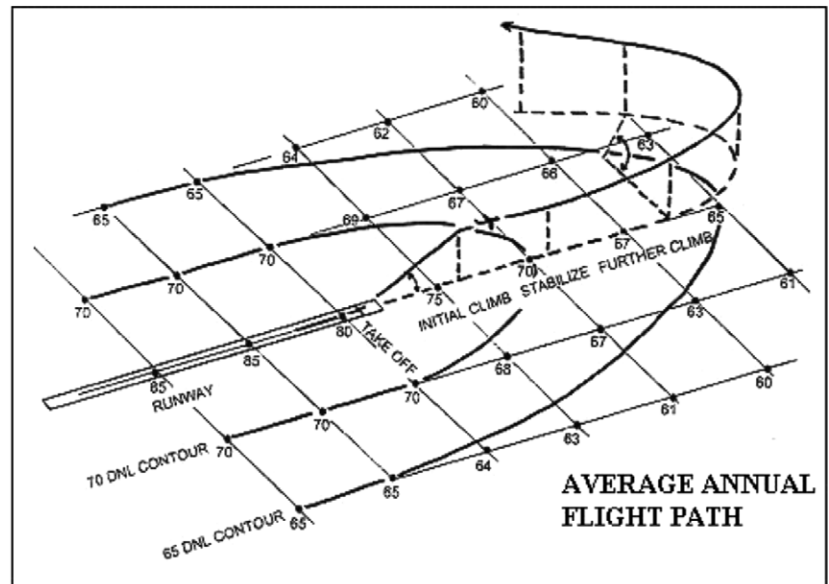


Fig. 2. Average annual aircraft flight path modelling in terms of noise contours. The latter are compiled from various sources giving information on airport characteristics, flight profiles, acoustics, and noise-power-distance relationships. Source: Airports Company South Africa.

investigation showed that there was no unified international approach to aircraft noise modelling at that stage and also no 'international model' to emulate. The decision was then taken to develop a uniquely South African model, the Noisiness Index (NI). The results were published in three documents called Codes of Practice SABS 0115, SABS 0116 and SABS 0117.¹⁵ The Noisiness Index is a deterministic model which uses noise emission values from specific aircraft types to calculate noise emission on a reference grid.

The need has arisen to revise the South African model, because of the difficulty in maintaining and modernizing the input database of noise emission values. Also, the NI cannot readily be integrated into or compared with noise caused by other sources, and according to the Airports Company South Africa (ACSA)¹⁵ has become outdated. In 2003, the SABS drafted a new National Standard, the SANS 10117:2003, which states that the INM is the noise prediction model of choice and that the noise descriptor to be used is the Yearly Equivalent Continuous Day-Night Level contour ($L_{Rdn,y}$). A major difference between DNL and $L_{Rdn,y}$ is the time weighting used. $L_{Rdn,y}$ incorporates a night weighting from 22:00 to 06:00, whereas DNL factors weighting from 22:00 to 07:00.^{27,28}

Noise control and modelling at Cape Town International airport

During the 1970s, the first issues regarding noise were being raised at the present CTIA, the first noise contours were plotted and the need to plan for a second runway was recognized. In 1986, the provincial planning department adopted the 70-NI noise contour line at CTIA as the limit for residential and other development. This was a contentious decision as the revised SABS 0117 recommended residential development up to 65 NI. Based on the small number of aircraft using the airport at that time, the 70-NI contour line was inside the land designated for airport purposes in the Urban Structure Plan of 1988. This allowed residential development to encroach almost onto the boundary of the airport.¹⁷

The Department of Transport²⁹ considers the regular calculation of noise contours to be essential. The only basis for recalculation of noise contours has been the SABS recommendation that this should be done every five years. In the absence of formal legal

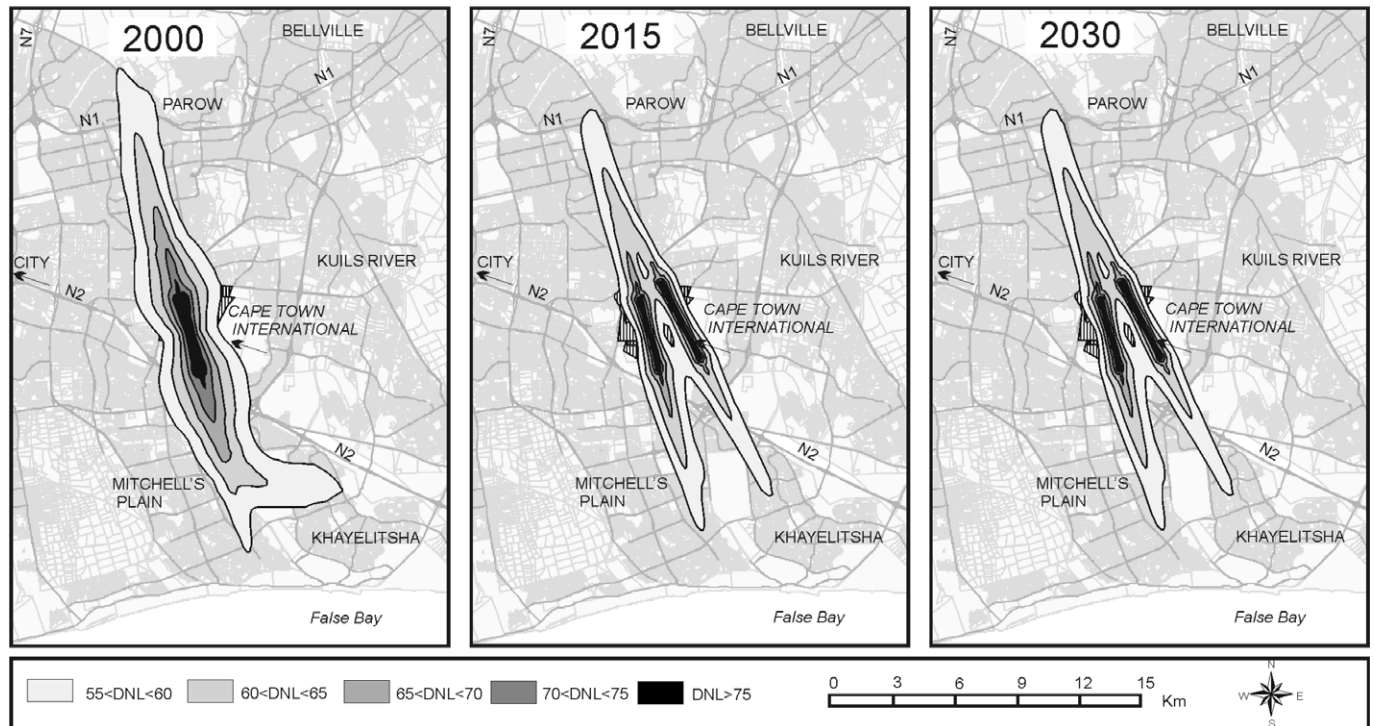


Fig. 3. The effects of an increase in the number of daily aircraft movements, between 2000 (before the phasing-out of Chapter 2 aircraft) and in 2015 and 2030 (after the introduction of the second runway) on the noise contour patterns around Cape Town International airport.

requirements for calculation and recalculation of noise contours, this did not take place for most of the airports in South Africa. Noise contours at CTIA were calculated for 1977, 1978, 1984 and 1990, using the NI Noise Prediction Model. The 1997 contours were calculated using the equivalent A-weighted sound level metric, which describes long-term or cumulative noise exposure of any duration, in the INM. ADR Planning (ACSA's international partners) produced the first DNL contours for the CTIA master plan update in 2000, using version 6.0a of the INM. These contours were produced to compare the environmental impact of the different scenarios identified for the configuration of the new runway in the long-term master plan for the airport.¹⁵

Figure 3 indicates how the noise contours for CTIA are affected by the increase in daily aircraft movements. The extensive 2000 impact pattern reflects the situation before the phasing out of old and noisy Chapter 2 aircraft. The two future simulations (for 2015 and 2030) show altered patterns of less noisy aircraft but ever-increasing traffic having to be accommodated on an added runway arranged in an open-V configuration. Impacts corresponding to the different scenarios quantified in Table 1 emphasize the large initial increase in affected area due to the projected increases in traffic volume before phasing out more than halves it. Thereafter, the added runway and further increases in flight traffic expand the areas once more. High impact zones remain at levels below that of 2000, however. In particular, the areas to the south and north of the airport are affected by the 55–75-DNL noise zone that will reach over 6000 hectares by 2030.

ADR Planning assumed the before and after phase-out dates of the Chapter 2 aircraft to be in 2008 and 2009, respectively, and therefore these dates were included in the calculations and contours mapped. The dates have subsequently been altered in the updated National Policy for Aircraft Noise and Engine Emissions (due for release). No additional Chapter 2 aircraft were to be permitted in South Africa after 1 January 2003. The phasing out, originally to have started on 1 January 2004 and to

have been concluded by 31 December 2010, has not been implemented because the Department of Transport failed to finalize the noise policy by February 2005. After phase-out, all fleets must consist of Chapter 3 aircraft.²⁹

The 'noise-controlled area' as a management instrument at Cape Town International airport

Efficient planning requires the formal demarcation of a 'noise-controlled area' around airports. The Western Cape Provincial Noise Control Regulations empower local authorities (the City of Cape Town in the case of CTIA) to do so. In section 2(f), the noise regulations define a controlled area as 'a piece of land designated by a local authority where the aircraft noise exposure level is above 65 dBA, projected for 15 years'.¹⁷ This translates to 65 DNL because nocturnal noise levels are adopted.

Various attempts were made to demarcate such an area around CTIA but nothing has been demarcated or implemented to date. The new zoning scheme regulations for the City of Cape Town will make provision for a 'controlled area' and an EIA must be completed for the second runway before such an area can be demarcated and published in the *Government Gazette*. Krynauw³⁰ states that "within a 'controlled area' [the City of Cape Town] may impose any appropriate conditions when granting permissions or exemptions in terms of the Regulations. This may include conditions related to the insulation of homes or other buildings in the conditions of establishment for a new township. [The City of Cape Town] may also require acoustic screening measures in new buildings or when extensions to buildings are considered. This will be applicable to new educational, residential, hospital, church or office buildings within the 'controlled area'. If a building is erected without the acoustic screening measure as imposed by [the City of Cape Town], a fine not exceeding R20 000 may be imposed."

This pronouncement reveals the dangers that local interpretation of regulations may hold for affected communities, because noise mitigation costs are normally borne by the airline industry

Table 1. Effect of the phasing-out of Chapter 2 aircraft, runway configuration and number of daily aircraft movements on the extent of the noise zones around Cape Town International airport.

Reference year	Runway configuration	Daily aircraft movements	Noise zone area (ha)				
			55–75 DNL	60–75 DNL	65–75 DNL	70–75 DNL	75 DNL
2000	Current	180	5796	2 668	1233	537	212
2008*	Current	335	8989	4 090	1845	866	355
2009**	Current	335	3090	1 320	507	207	93
2015	Additional runway with open-V configuration	418	3781	1619	549	255	123
2030	Additional runway with open-V configuration	680	6101	2662	988	398	176

*ADR Planning assumed phase-out of Chapter 2 aircraft in 2008. The phasing out, which was to have begun on 1 January 2004, had not been implemented at the time of going to press.

**ADR Planning assumed all Chapter 2 aircraft phased out by 2009. Final phase-out date is 31 December 2010.

¹See ref. 14.

according to the ‘polluter pays principle’.⁵ Simply stated: a socially concerned authority (and the relevant airport industry operators) may apply a liberal interpretation of regulations that would include a larger area and more people in the demarcated zone as beneficiaries of various mitigatory or compensatory measures. Likewise, less socially concerned role players may apply measures in such a way that expenses and mitigatory efforts are limited. To demonstrate these dangers in spatial terms, this research employs GIS to demarcate a controlled area objectively based on the 65-DNL noise contour for 2015, by identifying the extent of this area on the ground. DNL noise contours were used, since our study was completed before the publication of SANS 10117 and 10103,^{27,28} which prescribes Yearly Equivalent Continuous Day-Night Level contours. This has no serious implication for results here, since our aim is to show how the demarcated area (independent of the standard applied) may differ depending on the spatial demarcation principle employed.

GIS application in controlled area demarcation

The principal expenses at airports are the cost of infrastructure provision and the maintenance and mitigation of environmental problems.³¹ The ability of GIS to aid the management of infrastructure and the environment makes it a useful and economical planning tool to map noise contours and identify areas of unacceptable noise levels for sound-proofing programmes. Rowe and Caraway³² stress the utility of GIS as a decision-making tool when used to study alternative configurations for future expansion of airports by showing noise impact footprints from various proposed runway layout and aircraft profile scenarios. Harder³³ concurs that ‘studying the noise impact of flight operations on surrounding communities is a classic application of GIS thinking: it has a spatial component, a temporal component and is best communicated with a map.’

Two GIS spatial demarcation methods were used in this research: intersection and buffering. Intersection entails the topological integration of two spatial datasets that preserves features which fall within the spatial extent common to both

input datasets. Buffering is the process that creates a zone of fixed extent or distance around a point, line or polygon.³⁴ ArcView GIS version 3.2 was used to do a *select by theme selection*, which selects the features of the active themes that intersect with the features of the theme specified. The buffering option selects features within a certain distance of the theme specified. Note that ArcView’s implementation of intersection using *select by theme* implies that at least one point is common to both input datasets and therefore selects more than the area common to both input data sets with no boundary clipping.

Controlled area demarcation: data requirements, rules and options

Two spatial datasets are needed for the demarcation of controlled areas: the georeferenced aircraft noise contour lines and the underlying dataset of spatial units with practical, administrative utility on which to base demarcation. The definition of the controlled area provided earlier dictates that the 65-DNL noise contour line for the reference year 2015 should serve for demarcation. This implies that an era after the addition of an open-V dual-runway system and the phasing out of Chapter 2 aircraft is planned for. For the underlying spatial datasets, it was logical to use both cadastral (erven) and census enumerator areas as these are readily available in digital format, form legally bounded units (erven) or the basis for population information from which to identify affected and vulnerable populations (census tracts).

Selecting demarcation methods and options is fraught with practical difficulties and differences arising from different spatial frameworks and GIS methods employed for demarcation. The spatial units (erven, street blocks, enumerator areas) differ in extent and information content, whereas the various GIS methods (intersection, buffering) generate different results.

Demarcation options at CTIA

Six options selected to demarcate the noise-controlled area according to different rules are evaluated in the following section. The results are summarized in Table 2.

Table 2. Areal effect of controlled-area demarcation options.

Option	Spatial basis	GIS method	Contour (DNL)	Area (ha)	Units
1A	Cadastral erven	Intersection	65	1879	520
1B	Cadastral street blocks	Intersection	65	2245	31
1C	Erven and street blocks	Intersection	65	2317	1954
2	Enumerator areas	Intersection	65	2872	12
3	Cadastral erven	Buffering (100 m)	65	2000	1373
3	Cadastral erven	Buffering (200 m)	65	2116	2448
4	Cadastral erven	Intersection	64	1952	1061
4	Cadastral erven	Intersection	63	2008	1847
4	Cadastral erven	Intersection	62	2589	3144
4	Cadastral erven	Intersection	61	2733	5985
4	Cadastral erven	Intersection	60	3193	9585

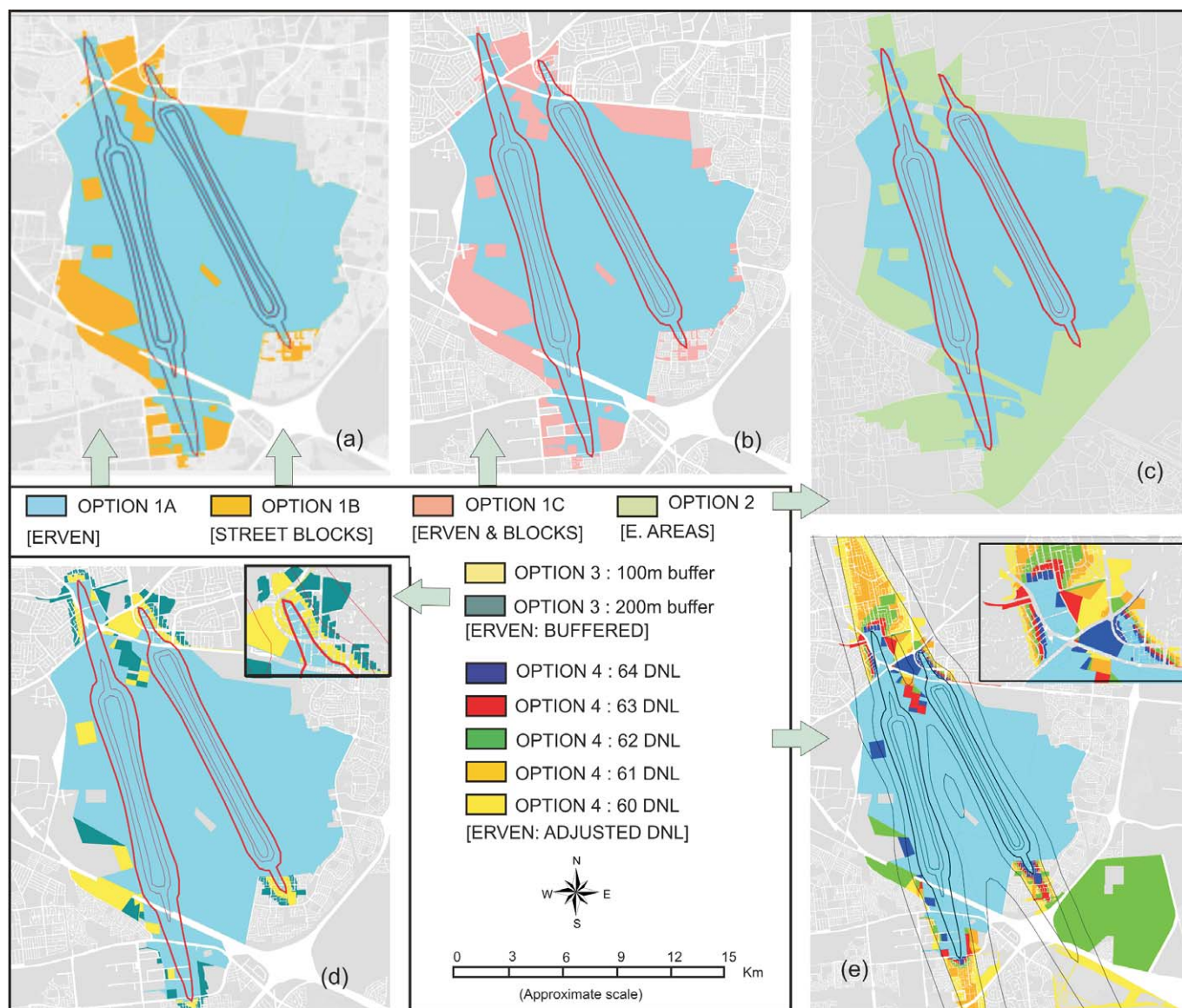


Fig. 4. Spatial implications of various controlled-area demarcation scenarios (options) around Cape Town International airport.

Option 1A: The 65-DNL contour on cadastral erven

The rule for this option was that all the cadastral property units (erven) that intersected with the polygon formed by the enclosing 65-DNL noise contour were selected. The resulting erven are highlighted in Fig. 4(a) and the corresponding area listed in Table 2. This option generates the smallest affected area (less than 2000 ha) of all the options.

Option 1B: The 65-DNL contour on street blocks

This option has the same rule as option 1A except that all the street blocks that intersected the polygon formed by the 65-DNL noise contour were selected. The reasoning here is that streets form good demarcation boundaries that isolate complete units in a relatively uniform area, notably where variably sized individual properties occur. It also reduces the possibility that property owners in the same street block (neighbours, in fact) in option 1A may appeal against their exclusion under that option — a less likely occurrence than when a full street block is included as a unit in the demarcated area. Also, the noise contour line is, by its very nature, a fuzzy intensity boundary that requires some leniency in its demarcation on the ground. On a gridded street pattern, even-sized units would be demar-

cated but, due to the shape of the anticipated 2015 noise contours and the curved streets in the vicinity of the airport, the demarcated area appeared jagged (Fig. 4 (a)). The total size increased by about 360 ha compared to that of option 1A (Table 2).

Option 1C: The 65-DNL contour on erven and street blocks

The rule for this option was that all cadastral erven which intersected with the area created by the street block option 1B were selected. This choice is viable if the affected units need to be identified as cadastral erven, but the street block demarcation criterion is desired. This creates the largest area of the three options discussed so far and includes almost four times as many erven as option 1A. Figure 4(b) demonstrates its spatial implications and Table 2 gives the corresponding area.

Option 2: The 65-DNL contour on census enumerator areas

When demographic information on the noise-affected community is required, census enumerator areas can be used, although it changes the resolution of the underlying spatial units. The rule is that all enumerator areas that intersect the polygon formed by the 65-DNL noise contour are selected. This scenario creates a relatively large area as indicated in Fig. 4(c) and Table 2. The

corresponding area incorporates more than 20 times the number of erven in option 1A. The area is some 1000 ha larger than that corresponding to option 1A and 500 ha more extensive than 1C.

Option 3: The buffered 65-DNL contour polygon

The reasoning behind this option was that, because of the fuzzy nature of the noise contour boundary, convincing affected communities that noise is a nuisance on the one side of the contour line but is not directly adjacent on the other side may create resistance to mitigation measures. To counter this potential problem, the critical contour line (65 DNL in this case) was buffered at 100 m and 200 m on the outside. The rule requires that all erven, enumeration areas or street blocks within these (buffered) polygons are variously selected as before. Figure 4(d) shows the significant difference between the different areas created so far. The obvious disadvantage of this scenario is that the buffer boundaries differ from the noise contours. The 100-m buffer almost reaches the 60-DNL contour, and in some places the 200-m buffer reaches the 55-DNL contour to the west and east of the airport where the contours are relatively close together.

Option 4: A different noise contour

Instead of buffering the 65-DNL contour line, a different contour line can be selected to incorporate a smaller or larger area than the 65-DNL polygon. Since contour lines indicate noise zones more accurately than buffer boundaries, contours were interpolated (by means of a GIS-generated grid) linearly at unit intervals between 60 and 65 DNL. Therefore, the rule here was that all erven, enumeration areas or street blocks that intersected the 60, 61, 62, 63 or 64-DNL contour were selected. A cautionary note should be added here: while the use of secondary generated contours for demonstration purposes is justified, primary modelled contours should always be used in actual demarcations. Figure 4(e) shows the difference in extent between the areas in property units earmarked by these lines, especially in the enlarged view of the area to the north of the airport.

Discussion and evaluation of the demarcation process and results

To obtain some practical value from these conclusions, the implications of various controlled-area options were rated, assessed and the best option was selected.

The rating criteria and evaluation procedure

The rating criteria used for evaluating the various options were: (a) the ease of the GIS procedure, (b) the resulting size of the demarcated area, (c) the practicality of the spatial unit used, and (d) the international support found for the particular option. The procedure entailed awarding a value of +1 (positive), 0 (neutral) or -1 (negative) to each option, according to the demarcation implications of the various criteria. The size of the 'controlled area' was rated according to the surface area in hectares and the number of spatial units contained in the area demarcated. The median for all options was calculated for both surface area in hectares and the number of spatial units. A value of 1 (above median), -1 (below median) or 0 (the median) was awarded to each option.

The convenience of the GIS procedure was rated according to the implications of data requirements, time and cost of application. The size of the area was ranked according to the social, economic and legal implications as explained below. The spatial unit used was rated according to the administrative practicality of the

unit to address noise issues. Lastly, the international support criterion was rated according to whether similar applications elsewhere have been reported in the literature.

GIS procedure

The main rating criterion here is ease of operation, which has data, time and cost implications. The GIS procedures used in the demarcation process are intersection and buffering, which are rather basic, easily understood and applied. The process becomes more complex and time-consuming if the data conversions from different units are necessary as in options 1B and 1C, or the contours are interpolated with new contour intervals as in option 4. In options 1B and 1C, the data have to be converted into street blocks by dissolving the inner boundaries of the cadastral data — a lengthy process in a large study area. To interpolate new contour intervals, a digital elevation model is created, or the INM is used to create new contours at logarithmic intervals. Both processes are more complicated and increase operational time. The ratings reported in Table 3 earmark options 1B, 1C and all the permutations in option 4 as complex and hence to be avoided from a computational point of view.

Size of the controlled area

The size of the controlled area was rated according to its social, economic and legal implications. Viewed from a community perspective, the number of properties protected should be maximized and therefore the larger the area and the greater the number of units included, the better. From the economic perspective of an agency or authority responsible for nuisance mitigation, compensation, or costs of residential sound insulation, the larger area or the more units to insulate, the more expensive the procedure. The legal perspective implies that in a larger area more people are subjected to the rules and regulations and the management or policing of the controlled area — a negative implication. The smaller demarcated area options (options 1A, both buffer options 3, and the 63-DNL and 64-DNL options in option 4) were rated higher in the economic and legal categories and lower in the social category (Table 3).

Practicality of spatial unit used

The spatial unit of the controlled area was rated according to the practicality of the unit to address noise issues. A controlled area defined in property units (cadastral erven) means that owners can be contacted, the number of units is easily calculated, and sensitive elements (such as schools and hospitals) are easily identifiable. Where enumerator areas define the controlled area, only access to population information to assess noise impact on people is improved and therefore option 2 was rated lower than the scenarios using cadastral erven. Option 1B was also rated lower because street blocks are less easily managed than erven because of their greater size.

International precedents

This criterion indicated whether a demarcation option was being applied at any airport elsewhere. For instance, the Orlando Aircraft Noise Overlay District uses a method of boundary determination similar to the intersection approach in which the plot is selected when a zone boundary line crosses or enters it.²² All the intersection options (options 1A, 1B, 1C, 2 and all the alternatives in option 4), therefore, received a positive value of 1 derived on the basis of this example.

Some of the same boundary determination methods used in the controlled area demarcation process were found in residential noise insulation programmes at the Minneapolis–St Paul,

Table 3. Rating of controlled area demarcation options.

Option	DNL contour	GIS procedure	Size: area			Size: number of spatial units			Practicality of spatial unit	International precedents	Rating
			(ha)	Score: social	Score: economic	Score: legal	(Units)	Score: social	Score: economic	Score: legal	
1A	65	Simple, quick	1879	-1	1	1	520	-1	1	1	6
1B	65	Complex, lengthy	2245 (median)	0	0	0	31	Street blocks not comparable	Street blocks not comparable	Street blocks not comparable	1
1C	65	Complex, lengthy	2317	1	-1	-1	1954 (median)	0	0	0	0
2	65	Simple, quick	2872	1	-1	-1	12	EAs not comparable	EAs not comparable	EAs not comparable	0
3	65 (100 m buffer)	Simple, quick	2000	-1	1	1	1373	-1	1	1	4
3	65 (200 m buffer)	Simple, quick	2116	-1	1	1	2448	1	-1	-1	2
4	64	Complex, lengthy	1952	-1	1	1	1061	-1	1	1	3
4	63	Complex, lengthy	2008	-1	1	1	1847	-1	1	1	3
4	62	Complex, lengthy	2589	1	-1	-1	3144	1	-1	-1	-1
4	61	Complex, lengthy	2733	1	-1	-1	5985	1	-1	-1	-1
4	60	Complex, lengthy	3193	1	-1	-1	9585	1	-1	-1	-1

Sydney and Adelaide airports. In the residential sound insulation programme at Minneapolis–St Paul airport, only homes wholly contained within or touched by the 65-DNL contour line are included. Intersect and ‘touch’ are regarded as synonymous in this case.³⁵ Option 1A (intersection with the 65-DNL contour) derived a value of 1 from this example.

From Sydney’s Kingsford Smith airport and Adelaide Airport in Australia, a method of boundary determination similar to the street block option 1B was reported. Where the noise exposure contour intersects a residential property within a street block, eligibility for insulation is extended out from the contour line to include all other houses in that street block up to a break in continuity of residential properties — normally a street or open area. According to the Australian Department of Transport and Regional Services,³⁶ this is done to prevent a situation where adjacent houses might be treated differently. Option 1B derived a value of 2 from these examples, one for each airport.

An optimal noise controlled area for Cape Town International airport

The four options with the highest ratings in Table 3 are 1A with a rating of 6, the 100-m buffering option (option 3) with a rating of 4, and the 64-DNL and 63-DNL contour options (option 4), both with a rating of 3. Because the buffering options disregard the shape of the noise contours and exclude many eligible units from protection, these options are disqualified. The complex and time-consuming GIS procedures necessary to create both alternatives in option 4 disqualify them when compared with option 1A, which is uncomplicated and quick to apply. Option 1A is also supported by more foreign examples. The evaluation therefore shows that the best method of demarcating the controlled area is option 1A, where all the property units (cadastral erven) that intersect the polygon formed by the 65-DNL noise contour are selected. Although changing future needs may require a more complicated solution, this option should prove to be the best and least complicated method to apply for demarcation purposes, once South African regulations regarding airport noise management are formalized.

Conclusion

This paper demonstrates the significant variation in impact that the demarcation of noise control areas by various methods may have. It especially emphasizes that the interpretation of regulations and technical decisions by local authorities and agencies may have profound implications for mitigating the effect of noise exposure on communities around our airports. We have shown that the optimum method of demarcating the controlled area is through GIS intersection of the spatial polygon formed by the 65-DNL noise contour with a property unit

(erven) cadastre, for which detailed records exist in the public domain at local authority level.

There are more pressing environmental threats than noise that face our urban population, but continuous noise at the local community level has adverse health effects and reduces the quality of life. Aircraft noise pollution is a factor with which airport management, airlines, town planners, government departments, environmental institutions and affected communities must deal. Research is therefore needed to understand better this multi-faceted phenomenon of aircraft noise, as well as the complex technical, environmental, social, political and legal issues that noise as an environmental problem raises for our communities, especially around airports.

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